Chapter 3
Circular Reinforced Concrete Pipe for Small Dams and Levees

3-1. General

Reinforced concrete pipe should be used for small dams, urban levees, and other levees where loss of life or substantial property damage could occur. Reinforced concrete pipe may also be used for less critical levees. Ancillary structures such as inlet structures, intake towers, gate wells, and outlet structures should be constructed with cast-in-place reinforced concrete. However, precast concrete may be used for less critical levees when designed and detailed to satisfy all loading and functional requirements.

3-2. Materials: Small Dams

a. Overview. Reinforced concrete pipe discussed in this chapter is designed by either the direct or indirect (*D-load*) method. This approach indirectly compares the moments and shears for the pipe section to a standard three-edge bearing test. The minimum diameter pipe used should be 1,220 mm (48 in.) to facilitate installation, maintenance, and inspection.

b. Reinforced concrete pipe through dams. Pipe through small dams should be concrete pressure pipe, steel cylinder type. Pipe joints should be deep or extra deep with steel joint rings and solid O-ring gaskets, and they should be used for the entire length of pipe between the intake structure and the stilling basin. The steel cylinder provides longitudinal reinforcement and bridges the gap if transverse cracks develop in the concrete. Steel joint rings can be readily attached to the steel cylinder. Reinforced concrete pipe with either steel end rings or a concrete bell-and-spigot joint can be used in less critical areas. Joints should have solid O-ring gaskets, and the pipe may or may not be prestressed. Also, a steel cylinder is optional. All acceptable pipe must be hydrostatic tested.

(1) Steel cylinder. When the steel cylinder is used, the cylinder should have a minimum thickness of 1.5 mm (0.0598 in.) and 25 mm (1 in.) minimum concrete cover.

(2) Prestress wire. When prestressing is used, the wire should have a minimum diameter of 5 mm (0.192 in).

(3) Mortar covering. The minimum concrete cover over prestressing wire should be 19 mm (3/4 in.).

(4) Concrete cover. The minimum concrete cover over plain reinforcing bars or welded wire fabric should be 38 mm (1.5 in).

(5) Cement. Cement used for concrete, grout, or mortar shall be type II.

(6) Steel skirts. These skirts are used on prestressed noncylinder concrete pipe to hold the steel ring in place. Skirts shall be welded to steel joint rings for noncylinder pipe, and longitudinal reinforcement shall be welded to the steel skirt for anchorage.

(7) Reinforced concrete pressure pipe, steel cylinder type. Design in accordance with American Water Works Association (AWWA) C 300. This pipe is designed by the direct method in accordance with AWWA C304.

(8) Prestressed concrete pressure pipe, steel cylinder type. Design pressure pipe in accordance with AWWA C 301. This pipe is designed by the direct method in accordance with AWWA C 304.

(9) Reinforced concrete pressure pipe. Design in accordance with AWWA C 302 or ASTM C 76. This pipe is designed by the indirect method (*D*-load).

3-3. Installation: Small Dams

Bedding conditions are illustrated for trenches in Figure 3-1 and for embankments in Figure 3-2. When precast concrete pipe is used for small dams, this pipe connects the intake structure to the stilling basin. The typical installation of this pipe is shown in Figure 3-3, which shows where to use two half lengths of pipe at connection to structures and the use of the concrete cradle. Deep or extra deep joints are of particular importance through the selected impervious material on the dam since this area is likely to experience the most settlement.

a. Reinforced concrete pipe. Reinforced concrete pipe through the select impervious material of the dam embankment should conform to either AWWA C 300 or AWWA C 301 between the intake structure and the stilling basin and maybe to AWWA C 302 in less critical areas of the dam, as shown in Figure 3-3.

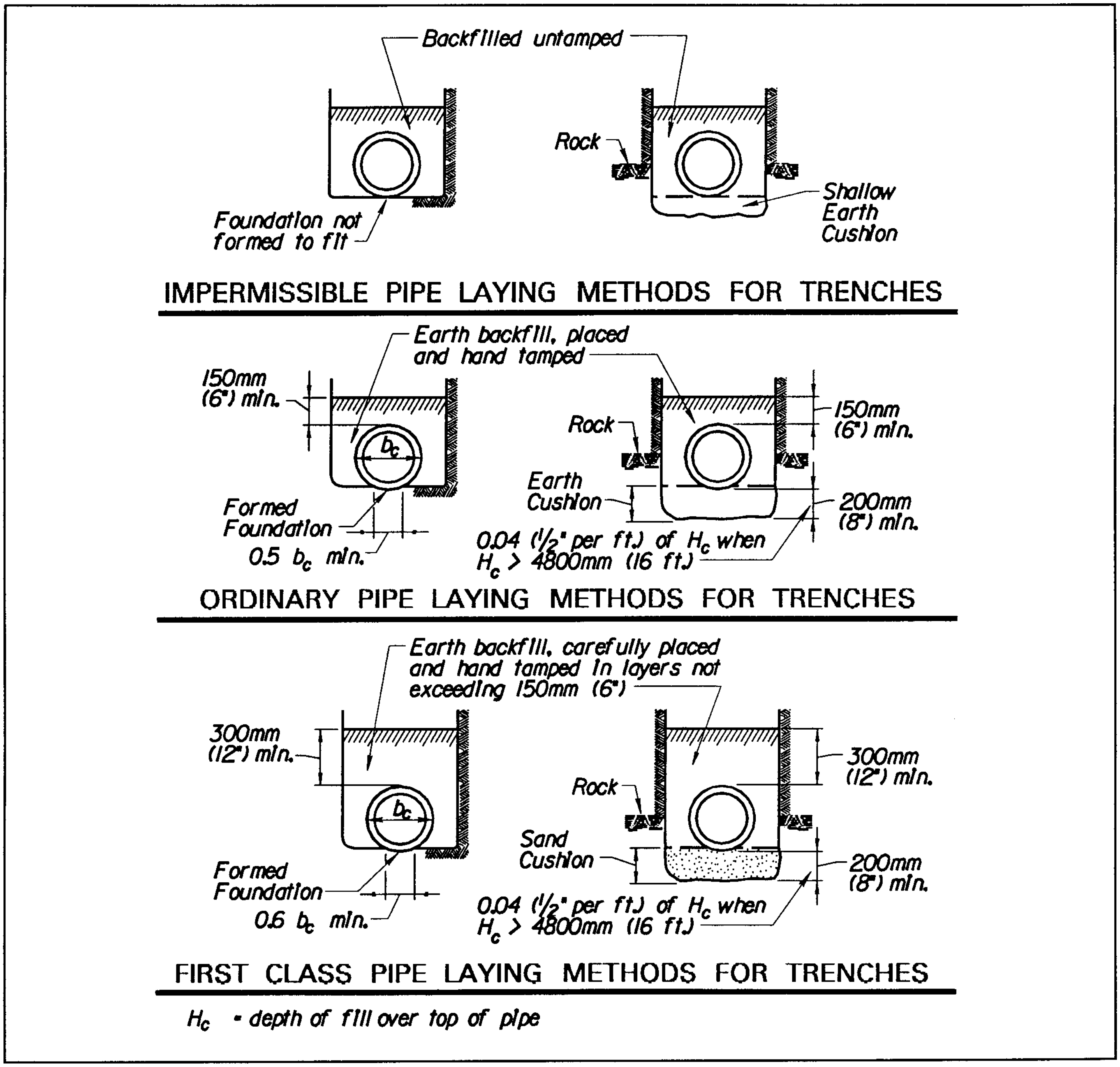


Figure 3-1. Trench bedding conditions

b. Cement-mortar grout. When concrete pipe is used, the exterior joint space should be grout-filled after pipe installation and hydrostatic tested, and the interior joint space should be grout- and mortar-filled after pipe installation, hydrostatic testing, and backfilling are completed.

c. Fittings and special pipe. These sections are used when there are alignment changes or connections to different sizes or types of pipe. The fittings and specials used should be designed for the same loading conditions as the regular pipe. Long-radius curves and small angular changes in pipe alignment should be made by deflecting the pipe at the joints or by using straight pipe with beveled ends, beveled adapters, or a combination of these methods. Beveling one end of straight pipe is often more economical than beveling both ends, and a combination of

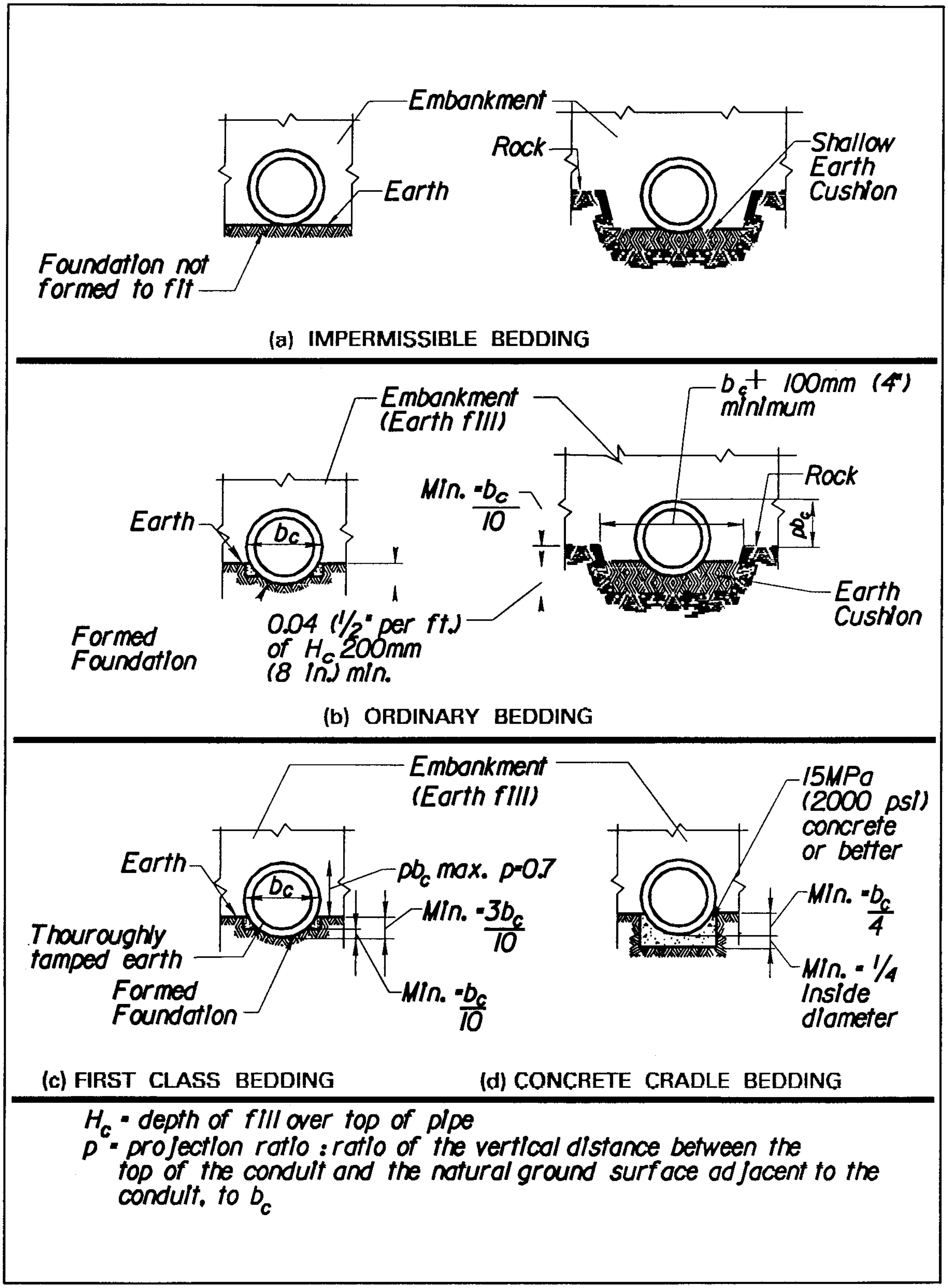


Figure 3-2. Embankment bedding conditions

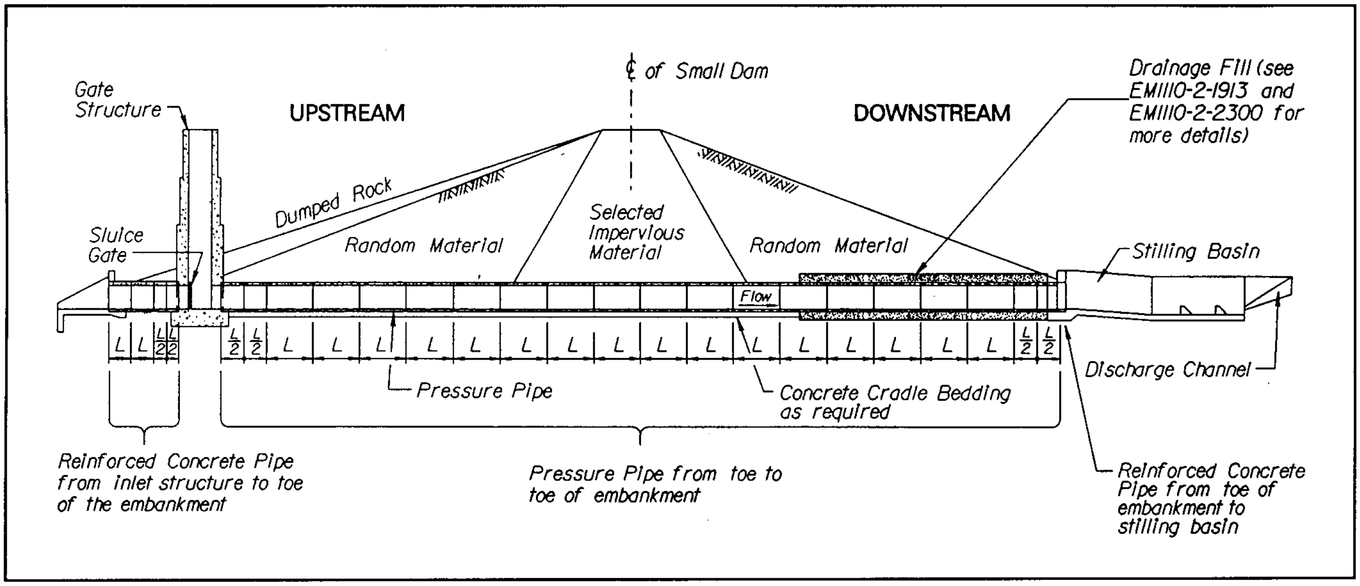


Figure 3-3. Reservoir outlet works (small dams)

straight and beveled pipe can be economical. Again, steel end rings should be used for fittings and specials.

d. Pipe laying lengths. Lengths of pipe used should not exceed 4.9 m (16 ft) for conduits when minimal foundation settlements are expected, and pipe lengths of 2.4 to 3.7 m (8 to 12 ft) should be used when nominal settlements are expected. Two half lengths of pipe should be used immediately upstream of the intake structure, immediately downstream of the intake structure, at the end of the concrete cradle, immediately upstream of the stilling basin, and when there is a change in the foundation stiffness.

e. Concrete cradle. Concrete cradles should be used to carry the conduit through soft foundation materials. The cradle is used between the intake structure and the point downstream where it is no longer required by the design, but not less than the toe of the major embankment section. Cradles are to be used for the first pipe length upstream of the intake structure and the stilling basin and under horizontal curves. Cradles should be terminated at the end of a pipe length. Disturbed foundation material should be backfilled to grade with lean concrete. Recompacting the foundation is not allowed.

f. Cradle reinforcement. Cradles should be continuously reinforced in the longitudinal direction with temperature and shrinkage reinforcement. The minimum amount of reinforcing steel in both directions should not be less than 0.002 times the gross area of the concrete. The transverse area of concrete is based on the concrete thickness below the pipe invert.

g. Dowels across joints. Joint dowels should be adequate to transfer the shear capacity of the cradle or the maximum differential load anticipated when an excess cradle capacity is provided. A compressible material with a minimum thickness of 13 mm (1/2 in.) should be used in the joint to accommodate slight foundation deflections.

h. Field testing joints. Joints for pipe through dams should be field-tested using a hydrostatic test after pipe is installed and prior to placement of the concrete cradle, the grouting or mortaring of joints, and the backfilling of the trench above the bedding. Hydrostatic testing should be 120 percent of the maximum design pressure for the pipe and in accordance with AWWA standard. An acceptable joint tester may be used for this testing requirement. Joints that fail the test should be replaced and retested until they are acceptable. Additional joint testing may be completed after backfilling, when watertightness is questioned.

3-4. Materials: Levees

Reinforced concrete pipe used in levees should meet the requirements of AWWA C 302 or ASTM C 76 as a minimum. The minimum diameter pipe for major levees should be 1,220 mm (48 in.) to facilitate installation, maintenance, and inspection. Other levees may have a minimum diameter of 910 mm (36 in.).

3-5. Installation: Levees

Pipes crossing under levees typically have a landside inlet structure, gate structure, and a floor stand. Figure 3-4 shows several possible variations for levee drainage structures. Two half lengths of pipe should be used at each structure connection to provide flexibility, as shown in Figure 3-5. Note that a granular drainage blanket is placed on the landside end third of the pipe.

a. Pipe laying lengths. Laying lengths should not exceed 3.7 m (12 ft) for conduits with normal foundation settlements, and these lengths should be reduced to 2.4 m (8 ft) when excessive settlements are expected. Two half lengths of pipe should be used at the upstream and downstream ends of the gate well structure, and when the foundation stiffness changes. When steel end rings are not used, a short concrete pipe should be laid through the wall of the gate well or intake structure, and the wall should be cast around the pipe as shown on the drawings. The mating end of the pipe should extend no more than 300 mm (12 in.) beyond the edge of the gate well structure, and the embedded end should have an appropriate waterstop.

b. Concrete cradle. Concrete cradles should be provided under the first length of pipe at the upstream and downstream ends of gate well structures. They should be doweled into the gate well slab to carry the full shear capacity of the cradle. The joint should be filled with a compressible material and have a minimum thickness of 13 mm (1/2 in.).

c. Field testing pipe joints. Joints for pipe through levees should be field-tested for watertightness using a hydrostatic test after pipe is installed, and prior to the grouting or mortaring of joints and the backfilling of the trench above the bedding. Hydrostatic testing should be in accordance with the appropriate AWWA standard. An acceptable joint tester may be used for this testing requirement. Joints that fail the test should be replaced and retested until they are acceptable. Additional joint testing may be completed after backfilling, when watertightness is questioned.

d. Gate wells. Gate wells should be cast-in-place concrete for major levees. Precast concrete gate wells may be used for less critical levees if designed and detailed to satisfy all loading and functional requirements. The loading requirements must include the maximum loads that can be applied through the gate lifting and closing mechanism. These mechanisms are usually designed with a factor of safety of five. This will usually

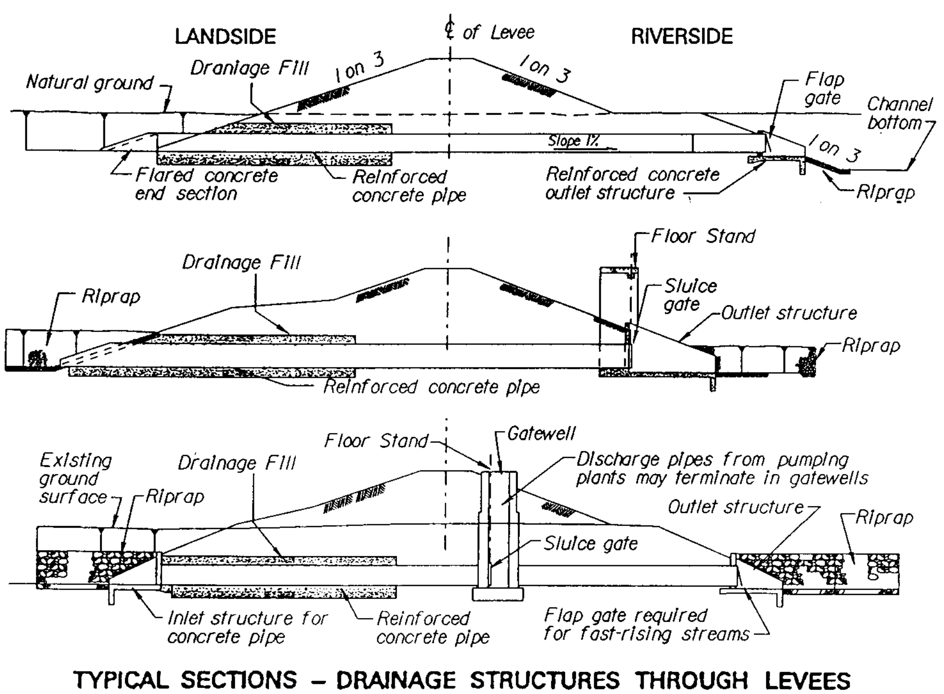


Figure 3-4. Typical sections, drainage structures through levees

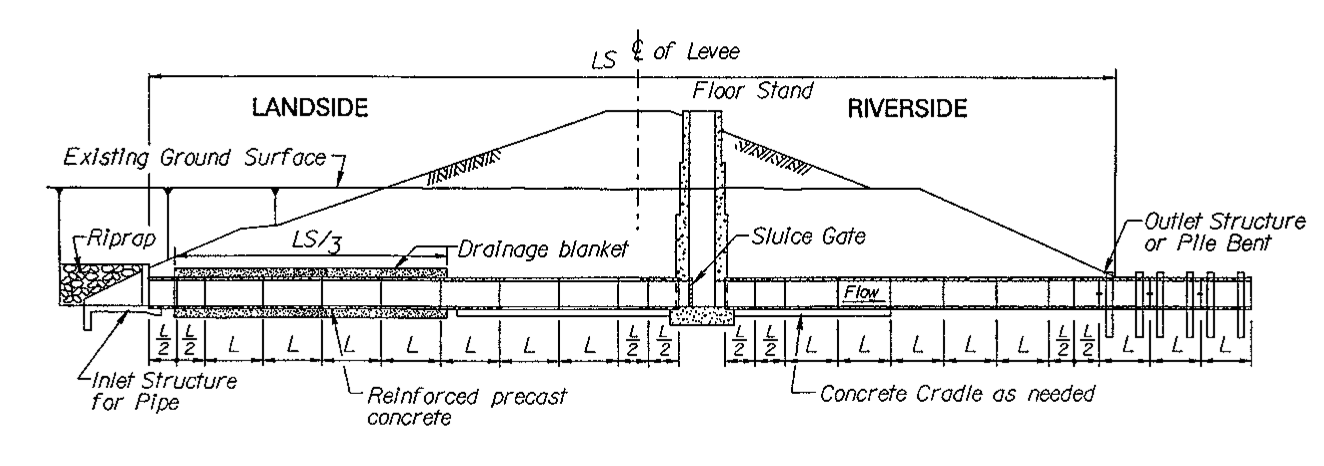


Figure 3-5. Typical precast conduit (levees)

require mechanical connections between pipe segments and additional longitudinal reinforcement in the pipe. The top, bottom, and gate frame must be securely anchored to resist all loading conditions. The joints for the gate well should be the same type as used for the pipe conduit. The installed gate well should be subjected to a hydrostatic test prior to backfilling.

e. Inlet structures. Inlet structures should be cast-in-place concrete in major levees, but may be precast as appropriate.

f. Outlet structures. Outlet structures are normally cast-in-place concrete, U-wall-type structures. Pile bents may also be used.

g. Pile bents. When pile bents are used to support a length of pipe, pipe lengths should be limited to 4.9 m (16 ft). Two pile bents, as shown in Figure 3-6, are required for each pipe section when using 2.4-m (8-ft) lengths of pipe, and three pile bents are required when pipe lengths are 4.9 m (16 ft). The two upstream sections of pipe beyond the pile bent should be two half lengths of pipe to develop joint flexibility. Mechanical connectors should be used on pipe joints when the pipe is supported on pile bents.

3-6. Loadings

The loadings used for precast concrete pipe are the same as those described in Chapter 2 for cast-in-place concrete pipe.

3-7. Methods of Analysis

a. D-load analysis. This analysis and the selection of pipe should be based on a $D_{0.01}$ crack using the approach in Section 17.4 of American Association of State Highway and Transportation Officials (AASHTO) (1996) with the following exceptions.

(1) Standard trench and embankment installations are presented in Figures 3-1 through 3-4, and paragraphs 3-3 and 3-5. The bedding factors B_f to be used for these installations are listed in Table 3-1. Bedding factors for the embankment conditions are shown in Table 3-2 and calculated using Equation 3-1:

$$B_f = \frac{1.431}{X_p - (Xa/3)} \qquad (3\text{-}1)$$

(2) For these installations the earth load, W_E should be determined according to the procedure in paragraph 2-4 for Condition I only, except H is equal to H_c.

(3) For these installations, the design load determined by AASHTO Equation 17-2 (AASHTO 1996) must be increased by a hydraulic factor H_f of 1.3, as shown in Equation 3-2, the modified AASHTO $D_{0.01}$ crack design equation:

* $$D_{0.01} = (H_f W_T)/(S_i B_f) \qquad (3\text{-}2)$$ *

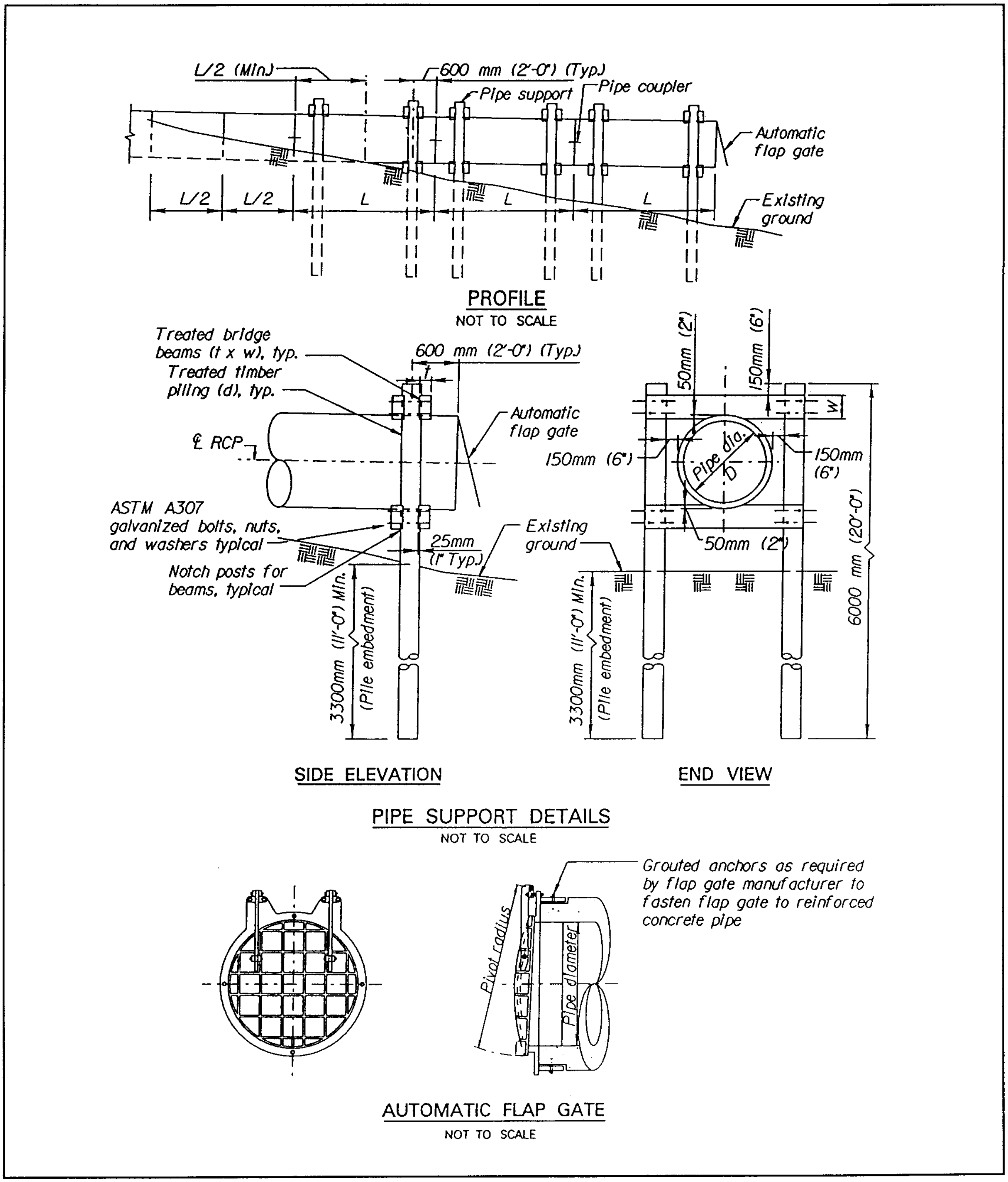


Figure 3-6. Typical pile bent

Table 3-1
Design Conditions: Trench

Type of Bedding	Bedding Factor B_f
Ordinary	1.5
First Class	1.9
Concrete Cradle	2.5

Table 3-2
Bedding Factor Constants: Embankment

Projection Ratio p	Concrete Bedding X_a	Other Projection Bedding X_a
0	0.15	0
0.3	0.743	0.217
0.5	0.856	0.423
0.7	0.811	0.594
0.9	0.678	0.655
1.0	0.638	0.638
	Type of Bedding X_p	
Ordinary		0.840
First Class		0.707
Concrete Cradle		0.505

where

$$W_T = W_E + W_F + W_L$$

and

H_f = hydraulic factor of 1.3

S_i = internal diameter or horizontal span of the pipe in mm (feet)

B_f = bedding factor. See Table 3-1 for trench condition and use Equation 3-1 with Table 3-2 for embankment condition

W_E = earth load on the pipe as determined according to the procedures outlined in Chapter 2, using case 1 only except replacement of H with H_c

W_F = fluid load in the pipe

W_L = live load on the pipe as determined according to paragraph 5-4

b. Multiple pipes. When several pipes need to be installed in the same trench, the designer must determine the loading condition to use. Two common installation conditions are shown in Figures 3-7 and 3-8. The soil columns used for this loading analysis are identified in these figures. The design method described below provides conservative results.

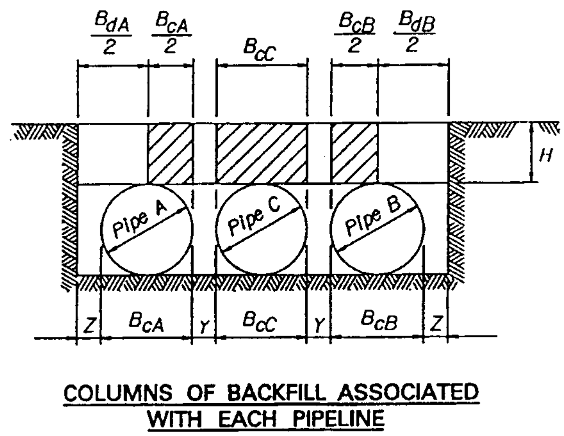


Figure 3-7. Multiple pipes in trench

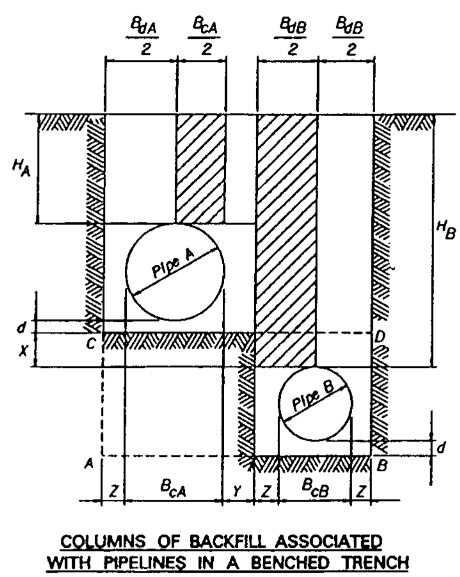


Figure 3-8. Benched pipes

(1) Trench condition. Load for multiple pipes varies from a simple trench condition to a projected embankment

condition, or even a combination of both within the same trench. Each pipe should be analyzed separately, and the transition width should be determined for each pipe. The transition width is the width of a trench when the trench load is equal to the projected embankment load. Therefore, trench loads cannot be greater than the projected embankment condition. The geometric relationship for three pipes in a trench is shown in Figure 3-7. If B_{cC} (the outside diameter of the center pipe) plus $2Y$ (twice the width of the soil column between the pipes in the trench) is equal to or greater than the transition width for the given size pipe, then pipe C is designed for a positive projected embankment condition. If the intermediate pipe spacing Y and the exterior pipe spacing to the trench wall Z are small compared to the outside diameter B_c and the height of fill H, then the entire earth load may be shared proportionately by the three pipes, and the entire installation is in a trench condition. Also, when the exterior pipe columns $B_{dA}/2$ or $B_{dB}/2$ are less than one-half of the transition width for either pipe (about 0.75 B_c), then the trench condition exists. However, the positive projected embankment condition exists when the width of these exterior pipe columns is greater than the transition width for the pipe. The interior columns are analyzed in a similar manner.

(2) Bench condition. When vertical and horizontal separation distances must be met, a common method of installing multiple pipes in the same trench is placing the pipe in a bench condition, as shown in Figure 3-8. When used, the stability of the bench needs to be analyzed, and load transfer between pipe "A" to pipe "B" is ignored. Two methods that may be used to install pipe in this condition are to excavate the full depth and full width of the trench, then backfill to the appropriate bench height before installing the second pipe; and to excavate a full-width trench to the top of the bench and then excavate the side trench. Once again, the geometry of the trench determines the loading condition on the pipe. When the soil columns B_{dA} and B_{dB} are less than the transition width for the pipe, the trench load is used. When these soil columns are greater than the transition width, the positive projecting embankment load is used. Normally, the trench will be excavated the full width to install pipe "B" then backfilled to the "CD" level, and pipe "A" is installed. This would place pipe "B" in a positive projecting embankment condition, and then pipe "A" must be analyzed for the transition width above the pipe crown.

3-8. Joints

a. In pipe. Joints for precast concrete pipe must resist the infiltration/exfiltration leakage, accommodate lateral and longitudinal movements, provide hydraulic continuity, and allow the pipe to be installed easily. Each precast manufacturer makes a pipe joint that conforms to one or more ASTM test requirements. Pipe with an integral O-ring gasketed joint should be used on pipe through small dams and levees. Mortar and mastic packing are not acceptable. The two types of joints specified by ASTM criteria, depending on the working pressure of the pipe, are ASTM C 443 and ASTM C 361. Working pressure rating for an ASTM C 443 pipe is 90 kPa (13 psi) in straight alignments and 70 kPa (10 psi) in axially deflected alignments. The working pressure rating for an ASTM C 361 pipe joint is up to 45.7 m (150 ft) of head. When specifying joints on precast concrete pipe through small dams or levees, pipe must have an integral O-ring gasket and pass the pressure test before the installed pipe can be accepted. Deep and extra deep joints should be specified for pipe in small dams and large levees where excess deflections are expected.

b. At structures. Integral O-ring gaskets and steel end rings are required at gate wells and gated outlet structures on small dams and major levees.

c. Testing. Pipe joints may be tested using an internal pressure.

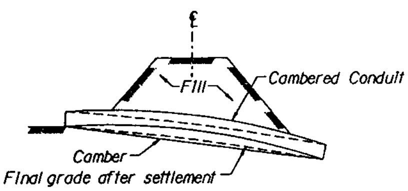
(1) Factory. Three ASTM tests are used to assure the pipe's integrity. First joints and gaskets shall be O-ring type in accordance with ASTM C 361. When pipe is *D-load* rated the strength capacity of the pipe will be determined by testing in accordance with ASTM C 497. Performance requirements for hydrostatic testing of pipe shall conform to ASTM C 443.

(2) Field testing with joint tester. All joints under embankments should be tested for leakage. Tests should include hydrostatic pressure tests on all concrete pipe joints under levees to be performed by the contractor after the pipe has been bedded and prior to placing any backfill. Testing of joints should be made by using a joint tester. Joints are required to withstand an internal pressure equal to the working pressure plus transient pressures for a duration of 20 minutes per joint. After backfilling the pipe, the contractor should perform additional hydrostatic tests on joints which by inspection do not appear to be watertight. Joints that fail should be disassembled and all inferior elements replaced. The possibility that some water may be absorbed by the concrete pipe during this test should be considered before rejecting the rubber seals proposed.

(3) Water-filled pipe test. Where practical, pipe joints can be tested for watertightness in the field by using the water-filled pipe test. The pipe should be free of air during this test and be maintained at the test pressure for a minimum of 1 hour. The possibility that some water may be absorbed by the concrete pipes during this test should be considered before rejection of the rubber seals proposed. Water should be added as necessary to maintain a completely full pipe at the specified head. On outlet works pipe, testing can be in increments as installed or for the full length after installation is completed.

3-9. Camber

Where considerable foundation settlement is likely to occur, camber should be employed to assure positive drainage and to accommodate the extension of the pipe due to settlement, as shown in Figure 3-9 (EM 1110-2-1913).



Camber allows for settlement of a culvert under a high fill. Most of the fall is in the outlet half. Diameters 3000mm (10 ft) and smaller are easier to camber, as are the lighter wall thicknesses.

Figure 3-9. Cambered conduit